Stochastic Power System Operations Toolkit

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FERC

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- Industry:
  - Kwok Cheung (Alstom)
- Academia:
  - Sarah Ryan (ISU)
  - David Woodruff (UC Davis)
- DOE
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Power System Planning/Operations

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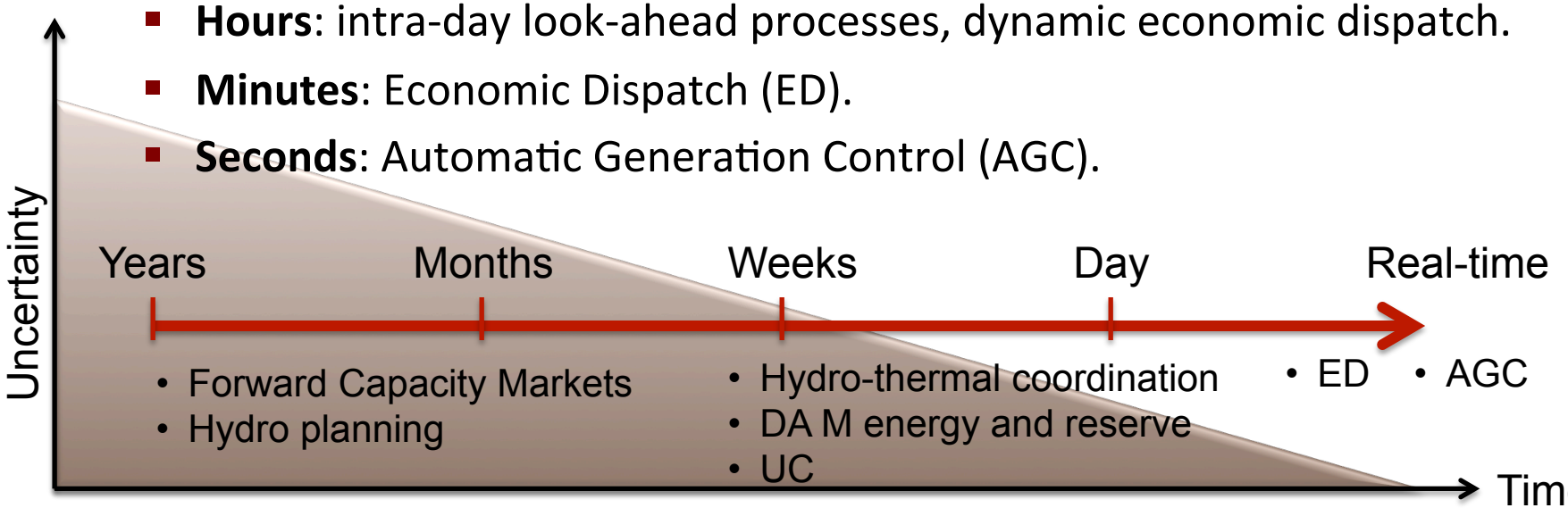
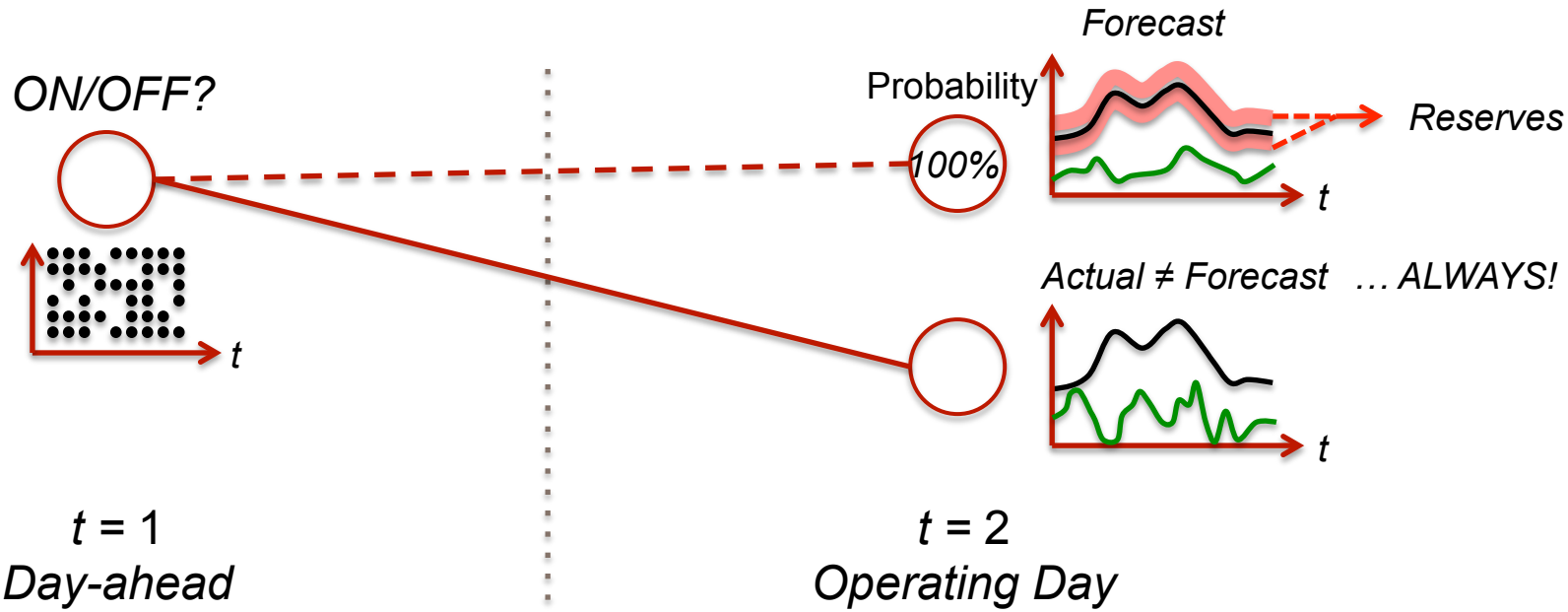
- Decision making in power systems looks at processes ranging from very large time constants to near real-time:
  - **Years, Seasons, Months, Weeks**: Resource adequacy, transmission and hydro resource planning.
  - **Days**: Hydro-thermal coordination, day-ahead UC of energy and reserves, intra-day UC.
  - **Hours**: intra-day look-ahead processes, dynamic economic dispatch.
  - **Minutes**: Economic Dispatch (ED).
  - **Seconds**: Automatic Generation Control (AGC).



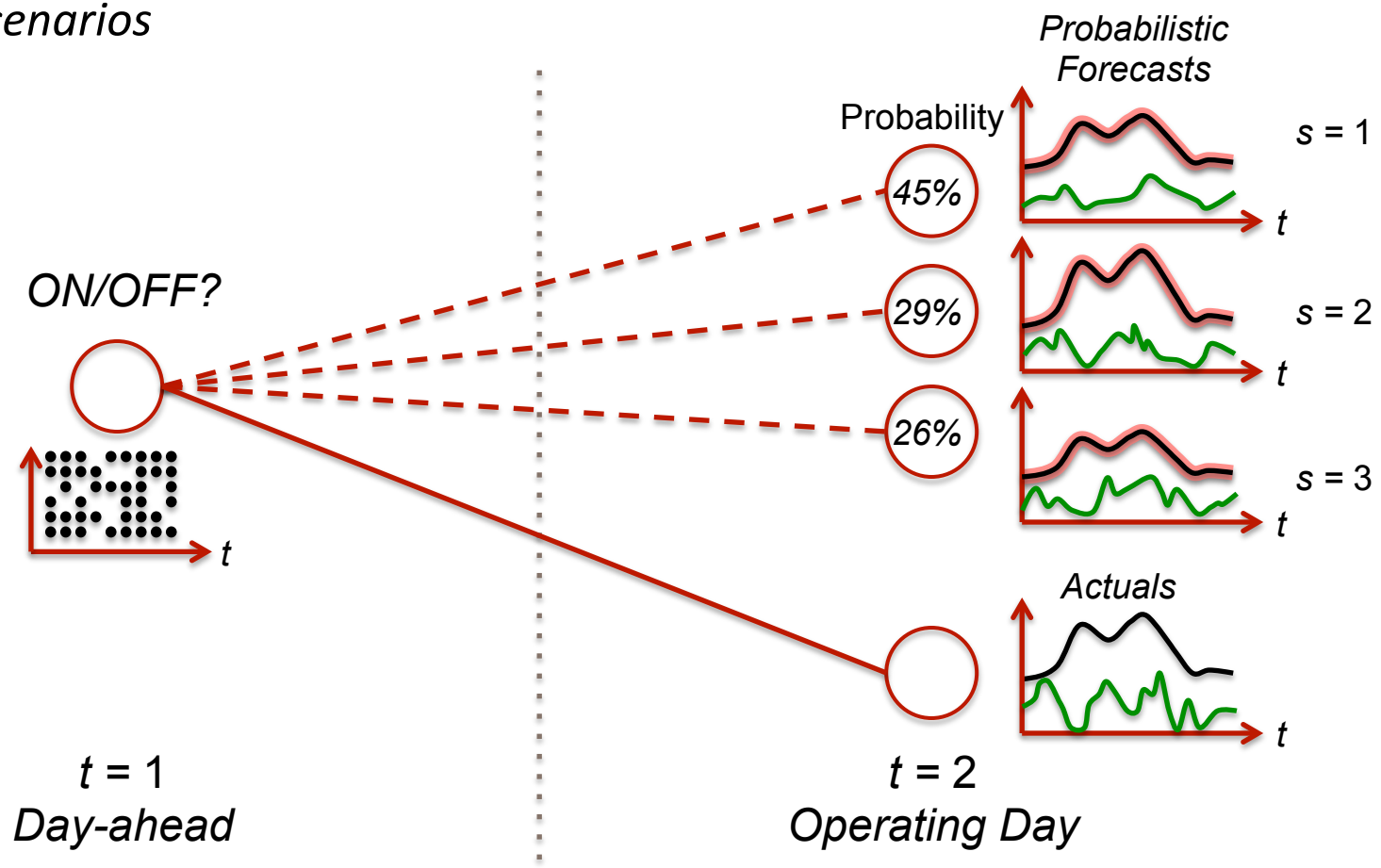
Unit Commitment (UC)

- Schedule generation resources (ON/OFF) such that generation costs are minimized while meeting the (net) load
  - Generation costs: Start-up/Shut-down costs, no load costs, fuel costs.
  - Net load = Load – Non-dispatchable generation (wind, solar)
- Subject to operating and physical constraints (generator min. up/down times, transmission limits, reserve requirements)



Stochastic Unit Commitment

- Schedule generation resources (ON/OFF) such that ***expected*** generation costs are minimized *under several load and renewable generation scenarios*



So Why Isn't Stochastic Optimization Deployed in Power Systems Contexts?

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- Modeling is significantly more complex
  - Stochastic process models, multi-stage decisions
  - Need data and significant expertise in both optimization *and* statistics

- Another reason is that stochastic optimization problems are in general exceptionally difficult to solve
  - Solve times *were* far from those required for operations problems (ARPA-e SNL-led project with UC Davis, ISU, Alstom, ISO-NE)

Project Goals

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- Create a stochastic operations toolkit for systems with high penetration of solar energy
  - Utilities can use to explore stochastic UC
  - Parametric and data driven stochastic models
  - Able to perform batch simulations
  - Open source
  - User friendly
- Demonstrate savings associated with using stochastic operations in a utility-scale test case
- Make toolkit available to the public and share test case findings with stakeholders

Power System Operations

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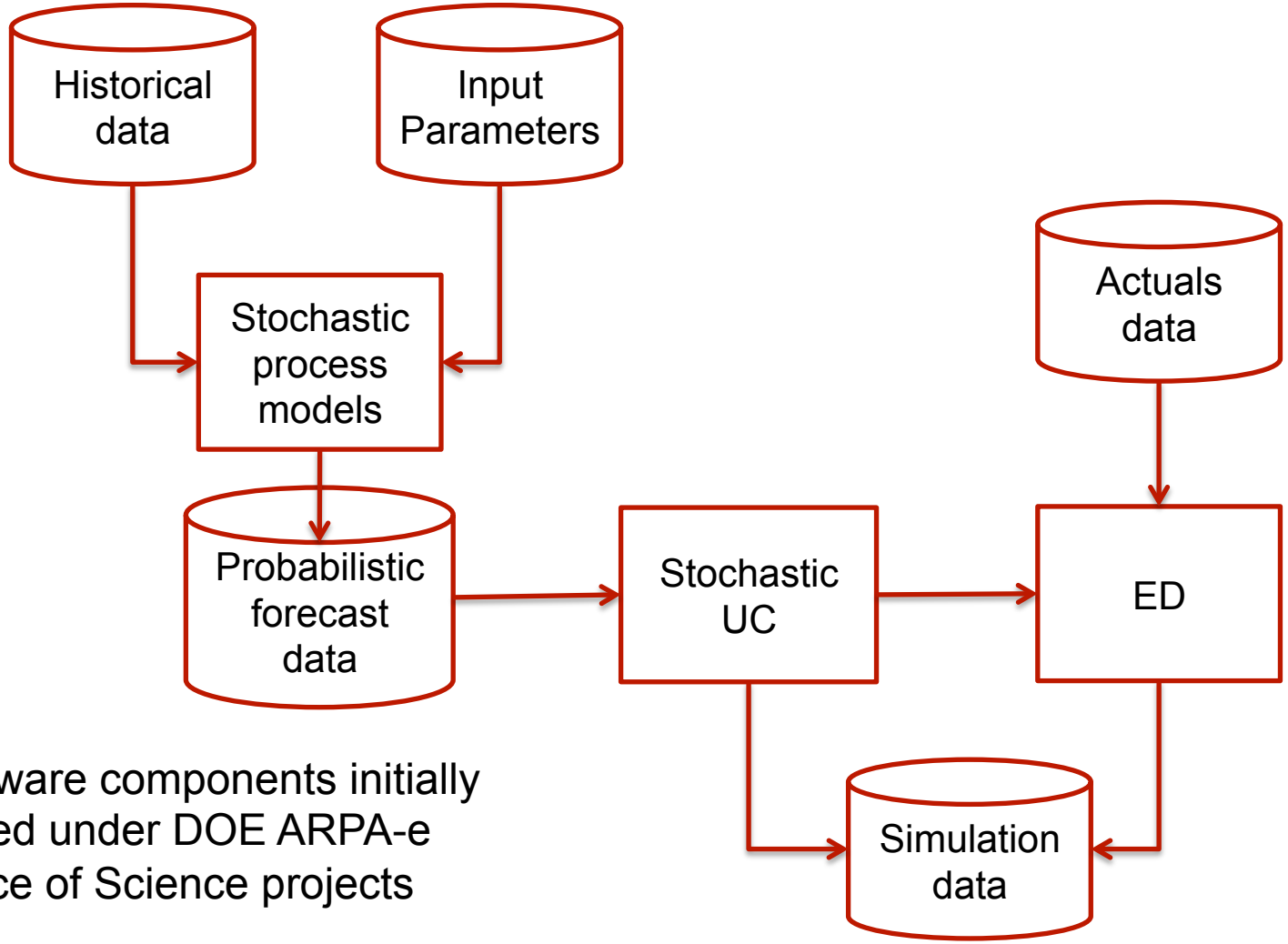
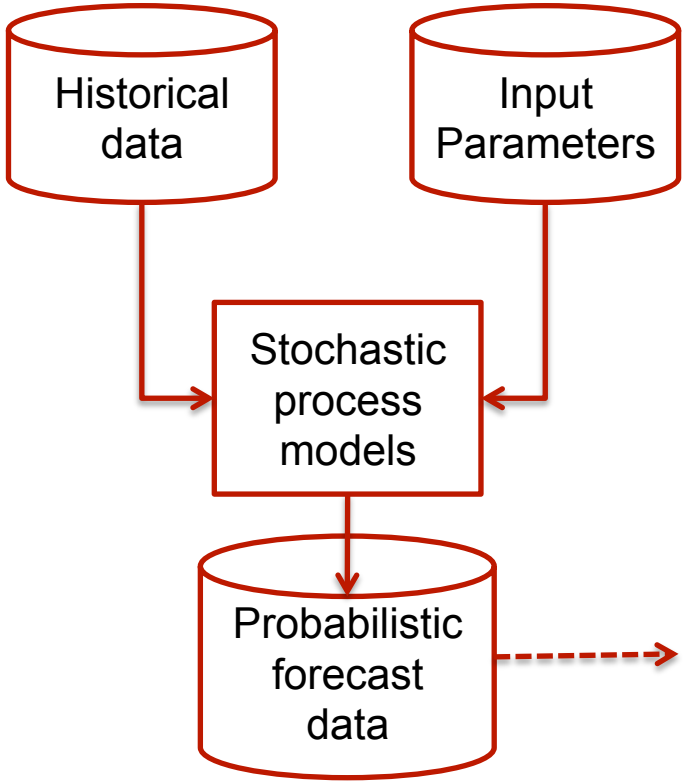
- Deregulated Regions
  - Day-Ahead Market
  - Reliability Unit Commitment
  - Intra-Day Commitment/Look-Ahead Dispatch
  - Economic Dispatch
- Vertically Integrated Utility
  - Day-Ahead Unit Commitment
  - Intra-Day Commitment/Look-Ahead Dispatch
  - Economic Dispatch

Toolkit Block Diagram



Key software components initially developed under DOE ARPA-e and Office of Science projects

Stochastic Process Models



- Parametric
  - Plant size, lat/long, altitude, tilt, etc.
  - Calculates clear sky index (using pv_lib* functions)
  - Assumes persistance forecast to calculate forecast error pdf
- Non-parametric
  - Solar power DA forecasts and actuals
  - If forecasts are not available, clear sky index persistance forecasts can be calculated
  - Forecast error pdf are calculated

*available at http://pvpmc.org

Stochastic UC

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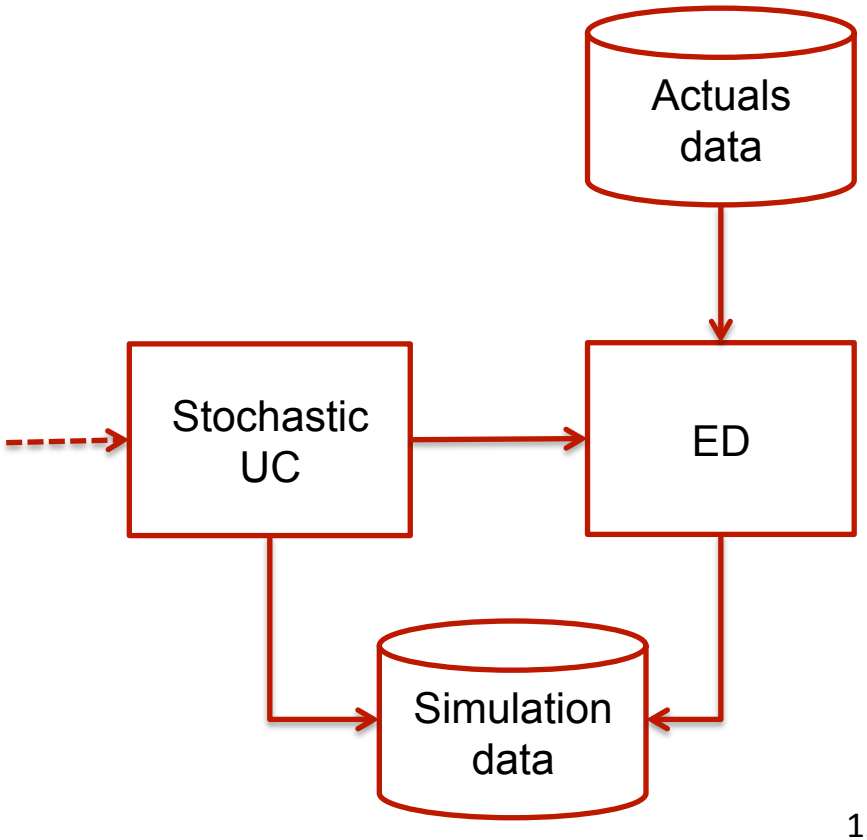
- 2 Stage Stochastic UC
- Minimize commitment (i.e., start-up and no-load) costs and expected dispatch costs to provide sufficient capacity to satisfy *forecasted* net load plus reserve requirements
- Hourly resolution (data-limited)
- Stochastic inputs:
  - Solar power plant output, demand
- Produces:
  - Generator commitments
  - Distribution of dispatch set points
- Solar plant output modeled as:
  - Must take – curtailed only for reliability
  - Dispatchable – curtailed for economics or reliability



Economic Dispatch

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- Deterministic
- Minimize cost of serving the net load *actuals* (load and solar power plant output)
- Hourly resolution (data limited)
- Produces:
  - Generator set points
- Uses commitment solution from stochastic UC
- NOTE:
  - Given higher-resolution load and forecast data, we can compute a stochastic economic dispatch in a straightforward manner

Running Modes

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- Multi-day simulation (batch)
  - Simulate operation for long periods of time
  - High data need: operator has access to multiple days of historical data for generator cost/offers, load and forecast of load and solar
  - Better reflects advantages of using stochastic operations

- Single-day operation
  - Run single day operation
  - Lower data need: operator has access to next day's load forecast
  - On any given day, stochastic UC results might produce better/lower operational costs than deterministic… or not

Conclusions

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- Several stochastic unit commitment computational barriers have been overcome
  - But it remains a difficult task in practice…
- Our objective is to provide software tools that reduce the implementation burden and help utilities/ISOs to get familiar with stochastic tools
- We are happy to talk with parties interested in using this tools in the future

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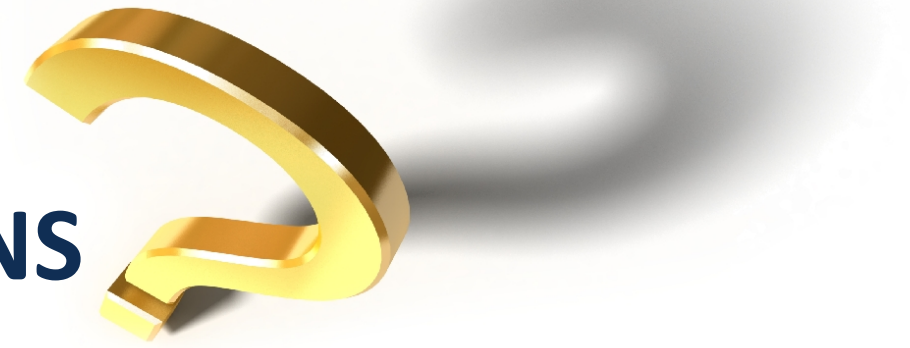
QUESTIONS



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